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DEVELOPMENT OF PERFORMANCE-BASED PHYSICAL SCREENING CRITERIA FOR THE U.S. NAVY FLEET DIVING PROGRAM

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TECHNICAL REVIEW AND APPROVAL

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The experiments reported herein were conducted according to the principles set forth in the current edition of the "Guide for the Care and Use of Laboratory Animals," Institute of Laboratory Animal Resources, National Research Council.

This technical report has been reviewed by the NMRI scientific and public affairs staff and is approved for publication. It is releasable to the National Technical Information Service where it will be available to the general public, including foreign nations.

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13. ABSTRACT *(Maximum 200 words)*

The current U.S. Navy fleet diver physical screening test has been found to be a poor predictor of representative physically demanding job performance. A mismatch between diver physical capabilities and job requirements may increase the risk of injury and decrease productivity. To improve physical selection procedures, an Experimental Fitness Battery (EFB) was validated against representative physically demanding diving tasks. The EFB contained measures of body composition, power, muscular strength, and swim endurance. Job tasks included: (1) Tool-bag swim, (2) 5-min fin-kick, (3) Ladder climb, (4) SCUBA-bottle carry, and (5) Umbilical pull.

Subjects were 146 male diver candidates (age 25.1 ± 4.3 yr, $\bar{X}$ ± SD, range 18-37 yr) undergoing training at the Naval Diving and Salvage Training Center, Panama City, FL. Results indicate a significant relationship exists between EFB scores and representative diving task performance. Although the EFB offers an improvement in job performance prediction compared to current selection criteria, caution should be used in implementing this battery for fleet diver physical selection purposes. Most of the variance in diving task performance cannot be accounted for by EFB scores. Greater emphasis should be placed on aligning physical training methods to meet job performance requirements.

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INTRODUCTION

In response to Chief of Naval Operations tasking (1), a series of studies were undertaken by the Naval Medical Research Institute to develop performance-based physical selection standards for the U.S. Navy Fleet Diving Program.

Using a task-analytic approach, an initial study identified a number of representative tasks performed by U.S. Navy fleet divers (2). A subsequent validation study found the current entry-level fleet diver physical screening test provides a poor estimate of representative diving task performance (3).

In order to develop a performance-based physical screening test, the purpose of the present investigation was to evaluate an Experimental Fitness Battery (EFB) from which the most predictive measures of diving task performance could be selected for physical screening purposes. The development of performance-based physical selection criteria for the U.S. Navy Fleet Diving Program may lead to substantial cost savings through enhanced screening, safety, and productivity.

METHODS

Subjects

One-hundred and forty-six male diver candidates (age 25.1 ± 4.3 yr, $\bar{X}$ ± SD, range 18-37 yr) participated in the study. Diver candidates were participating in first class, second class, diving medical technician, and basic diving officer training at NDSTC.

Only subjects who met current entry-level physical screening test standards were tested. Since candidates generally perform to minimum standards on the first physical

screening test, scores presented here are from the second screening test, which was a maximal effort. Due to schedule conflicts, medical waivers, attrition, etc., a number of individuals did not complete the second physical screening test and all job tasks.

After procedures were explained in detail, subjects gave written informed consent. All participants passed a physical examination to screen for medical conditions that could increase the risk of injury during testing. This study was approved by the Committee for the Protection of Human Subjects at the Naval Medical Research Institute, Bethesda, MD.

Figure 1. Diver candidate attempts shoulder press test as a part of Experimental Fitness Battery testing.

Experimental Fitness Battery

The Experimental Fitness Battery (EFB) included the following test items: lean body weight, percent body fat, standing long jump, leg press, shoulder press, lat pull, arm curl, and 1000-yd fin-swim. The following criteria were used to select these fitness measures:

(1) Measured a basic component of physical fitness

(2) Recognized history in performance assessment

(3) Ease of administration

(4) Reliability

Test administration procedures for the EFB are as follows:

1. <u>Body composition</u> - Percent body fat was assessed by circumference measurements according to procedures outlined in OPNAVINST 6110.1D (4). Total body weight (lbs) was determined so that lean body weight (lbs) could be calculated.

2. <u>Standing long jump</u> - Subjects were instructed to jump forward to cover as much horizontal distance as possible. Jump distance was measured from the starting line to the body part touching the deck closest to the starting line (to the nearest 0.5 inch). The longest of three trials was used as the final score.

3. <u>Leg Press</u> - One repetition maximum for the leg press was determined on a commercial exercise machine. Subjects were instructed to sit erect with their lower back against the back of the seat, legs flexed with feet against the pedals and hands grasping the hand grips. Subjects performed several warm-up repetitions, then attempted a maximal lift starting at 150% of body weight. Weight was progressively increased until a maximal lift was accomplished. Maximal weight (lbs) lifted was recorded.

4. Shoulder Press - One-repetition maximum strength for the shoulder press was determined on a commercial exercise machine. Subjects were instructed to sit facing the machine, shoulders touching handles, back erect, feet flat on floor. Subjects performed several warm-up repetitions, then attempted a maximal lift starting at 50% of body weight. Weight was progressively increased until a maximal lift was accomplished. Maximal weight (lbs) lifted was recorded.

5. Lat Pull - One repetition maximum for the lat pull was determined on a commercial exercise machine. Subjects were instructed to face the machine and sit directly under the bar and then to pull the bar down to the back of their neck. Subjects performed several repetitions, then attempted a maximal lift starting at 50% of body weight. Weight was progressively increased until a maximal lift was accomplished. Maximal weight (lbs) was recorded.

6. Arm curl - One repetition maximum for the arm curl was determined using free weights. Subjects were instructed to grab the bar with palms facing towards the body and curl the weight in an arc towards the shoulders. Subjects performed several warm-up repetitions, then attempted a maximal lift starting at 50% of body weight. Weight was progressively increased until a maximal lift was accomplished. Maximal weight (lbs) was recorded.

7. 1000-yd fin-swim - The swim was conducted in open water adjacent to NDSTC. Divers were dressed in wet suit, mask, and fins. Time (min) to complete the 1000 yd course was recorded.

Job Performance Assessment Battery

Job performance assessment battery development was based on survey and interview data provided by U.S. Navy fleet divers, objective work-site measurements collected at NDSTC, and an extensive review of videotape data (1). The final selection process took into consideration potential testing problems that might be encountered in a field setting such as extensive use of operational equipment, time consuming test procedures, the need for a large test administration staff, and safety issues. The representative tasks included in the job performance assessment battery are described below:

In-Water Tasks

1. Tool-Bag Swim - SCUBA diver (wearing twin 80s, breathing air) swims a distance of 200 ft while carrying a 24-lb tool bag.

This task was conducted in the NDSTC swimming pool. A dive team and safety diver were present during all testing. Subjects wore twin 80 SCUBA and breathed air. Subjects started the task in the water along one side of the pool. They were instructed to swim across the width of the pool (a distance of 50 ft) and then return. This was repeated again so that a total distance of 200 ft was covered. Subjects carried the tool bag on one arm and were allowed to rest, if necessary, along the side of the pool. Performance was scored as pass/fail (i.e., subjects who passed were able to swim the entire distance without contacting the bottom).

2. Fin-Kick - SCUBA diver (wearing twin 80s, breathing air) attempts to remain on surface by fin-kicking.

This task was conducted in the NDSTC pool. A dive team and safety diver were present at all times during testing. This task was designed after the current water survival test conducted at NDSTC. Subjects wore twin 80s, but did not breathe from the regulator. The task was started in the water and subjects were instructed to remain afloat by fin-kicking and to raise their arms and hands out of the water. Performance was scored as pass/fail (i.e., subjects who passed were able to stay on the surface for a period of 5 min).

Shipboard Tasks

3. Ladder Climb - MK-21 diver (fully weighted, single SCUBA, breathing air) descends/ascends a 14-ft vertical ladder.

This task was conducted in the NDSTC open tank. The tank was not filled with water during the testing period. Subjects were dressed in MK-21 gear, breathing air (helmet, 28-lbs; boots, 12-lbs; IDV and weights, 38-lbs; single SCUBA, 32-lbs). Subjects were instructed to climb down the ladder until both feet were on the bottom of the tank and then ascend the ladder as quickly as possible. The task started with subjects standing on the tank deck and ended when the subjects returned to this position. Tenders controlled the umbilical line to ensure safety. Performance was scored as the total time (min) required to descend/ascend the ladder.

4. SCUBA-Bottle Carry - Diver lifts/carries twin 80 SCUBA bottles a distance of 450 ft (including up/down ship's ladder).

This task was conducted on the pier and NDSTC training craft. Prior to testing, the task was demonstrated using proper lifting technique. Subjects were instructed to perform the following tasks:

(a) Lift the twin 80 SCUBA bottles from the pier.

(b) Carry the SCUBA bottles onto the training craft, down an inclined ladder, and set them down in a dive locker (a distance of 75 ft).

(c) Lift the SCUBA bottles and carry them back up the ladder to the starting point.

(d) Repeat this task 3 times.

Subjects were advised to walk as fast as possible throughout the entire course but not to run. Subjects were instructed to carry the twin 80 SCUBA bottles horizontal to the deck in front of their bodies. Subjects were allowed to walk through the course for practice. Monitors were positioned by the ladder to ensure safety. Performance was measured as the total time (min) required to complete the task.

5. Umbilical Pull - Topside diver pulls an umbilical line (weighted to 100 lbs) a distance of 50 ft.

This task was conducted in the ascent tower. Prior to testing, the task was described and demonstrated. Divers were instructed to pull an umbilical line (weighted to 100 lbs) a distance of 50 ft. Subjects were allowed to pull the weight a short distance off the bottom for practice. Performance was scored as total time (min) required to pull the weight to the surface.

Statistical Analysis

Descriptive statistics including means, standard deviations, and ranges were determined to describe diver physical characteristics (i.e., age, height, etc), and provide EFB and job task data.

Comparison of EFB scores for diver candidates who passed/failed the in-water job tasks (i.e., fin-kick and tool-bag swim) was assessed using paired t-tests.

Multiple regression techniques were employed to develop regression equations for predicting shipboard job tasks (i.e., climb ladder, lift/carry SCUBA bottles, and pull umbilical line) from EFB scores. Fitness measures entered the equation in a forward stepwise fashion. Minimum tolerance was set at 0.15 for variables entering the equation.

RESULTS

Descriptive statistics of the diver candidates are found in Table 1. The percentage body fat of diver candidates was found to be substantially lower (12.8, ±3.7, $\bar{X}$ ± SD) than values reported for Navy recruits (14.5, ± 4.2, $\bar{X}$ ± SD), auxiliary ship personnel (16.4, ± 5.3, $\bar{X}$ ± SD), or submarine personnel (16.1, ± 5.5, $\bar{X}$ ± SD) (5).

Table 1. Descriptive Statistics of Diver Candidates (N=146)*

VARIABLE	MEAN	S.D.	RANGE
Age (yrs)	25.1	± 4.3	18.0-37.0
Height (in)	69.3	± 2.4	63.5-77.0
Weight (lbs)	170.5	± 17.9	130.0-216.5
Fat Weight (lbs)	22.3	± 8.1	5.9-42.6
% Fat	12.8	± 3.7	4.0-23.0
Lean Body Weight (lbs)	148.4	± 13.1	108.8-189.2

* N=145 (Fat Weight, % Fat and LBW)

EFB and job performance scores for diver candidates are presented in Tables 2 and 3, respectively. The muscular strength scores of diver candidates was substantially higher than those observed in other Navy populations (6). For example, the mean shoulder press score for diver candidates was 158.8 lb compared to 101.6 lb (staff) and 115.9 lb (recruits).

Table 2. Experimental Fitness Battery Scores of Diver Candidates (N=146)*

VARIABLE	MEAN	S.D.	RANGE
Long Jump (ft)	7.2	±0.7	5.3-8.7
Leg Press (lbs)	457.3	±73.5	290.0-560.0
Shoulder Press (lbs)	158.8	±23.8	100.0-230.0
Lat-Pull (lbs)	178.1	±23.2	120.0-220.0
Arm Curl (lbs)	114.2	±16.7	65.0-170.0
1000yd Swim (min)	20.9	±2.2	14.8-29.3

* N=88 (1000yd Swim)

Table 3. Job Performance Assessment Battery Scores of Diver Candidates

VARIABLE	N	MEAN	S.D.	RANGE
Swim/Carry Tool Bag (min)	70	2.2	± 0.8	1.3-4.4
Fin-Kick (min)	71	4.7	± 0.6	2.7-5.0
Climb Ladder (min)	88	0.4	± 0.1	0.2-0.7
Lift/Carry SCUBA Bottle (min)	125	4.6	± 1.0	2.7-7.1
Pull Umbilical (min)	118	0.7	± 0.2	0.3-1.6

A comparison of physical screening test scores for candidates who passed/failed the two in-water tasks can be found in Tables 4 and 5. EFB scores of candidates passing were significantly higher than those of task failures in two instances (1000-yd swim for the tool-bag swim, $P < 0.05$, Table 4) and (lat pull for the fin-kick task, $P < 0.05$, Table 5).

Table 4. Comparison of Experimental Fitness Battery Scores For Candidates Passing\Failing Tool-Bag Swim Task

	PASS GROUP (N=57)*		FAIL GROUP (N=13)		
	MEAN	S.D.	MEAN	S.D.	T
Long Jump (ft)	7.2	±.6	7.4	±.7	1.2
Leg Press (lbs)	476.7	±67.0	446.5	±71.2	-1.4
Shoulder Press (lbs)	157.4	±25.7	163.1	±24.6	.7
Lat-Pull (lbs)	184.7	±22.7	173.8	±29.6	-1.5
Arm Curl (lbs)	113.8	±17.5	113.5	±19.0	-.6
1000yd Swim (min)	19.8	±1.8	21.4	±2.2	2.3**
Lean Body Wt. (lbs)	148.3	±13.0	145.7	±16.2	-.6
% Body Fat	12.9	±3.6	12.9	±3.0	.4

* N= 28 Pass, 11 Fail for 1000yd Swim
** Significant Group Difference (P<0.05 Level)
T=Pooled Variances T

Table 5. Comparison of Experimental Fitness Battery Scores For Candidates Passing/Failing Fin-Kick Task

	PASS GROUP (N=54)*		FAIL GROUP (N=17)		
	MEAN	S.D.	MEAN	S.D.	T
Long Jump (ft)	7.1	±.6	7.5	±.7	-1.8
Leg Press (lbs)	470.4	±70.0	464.7	±67.8	.3
Shoulder Press (lbs)	154.6	±25.9	167.0	±23.6	-1.8
Lat-Pull (lbs)	186.1	±22.9	172.3	±25.1	2
Arm Curl (lbs)	113.9	±16.9	112.3	±20.1	.3
1000yd Swim (min)	19.9	±2.1	20.7	±2.0	-1.3
Lean Body Wt. (lbs)	147.7	±13.6	148.2	±13.8	-.1
% Body Fat	12.8	±3.4	12.6	±3.2	.2

* N=26 Pass, 15 Fail for 1000yd Swim
** Significant Group Difference (P<0.05 Level)
T= Pooled Variances T

The regression of shipboard tasks on the EFB is illustrated in Table 6. The EFB provided a moderate prediction of shipboard task performance.

Shipboard task predictors were:

- Long jump, leg press, and percent body fat scores (Climb ladder, R = .33, S.E.E. = .15)
- Lat pull (Lift/carry bottle, R = .33, S.E.E. = .67)
- Lean body weight (Pull umbilical, R = .47, S.E.E. = .18)

Table 6: Prediction of Shipboard Tasks from Experimental Fitness Battery Scores

JOB TASKS	PREDICTORS	MULT R	RSQ CHANGE	B*	S.E.E.**
Climb Ladder	Long Jump	.24	.06	-0.06	
	Leg Press	.29	.08	0.00	
	Percent Fat	.33	.11	0.00	
	(constant)			.80	.15
Lift/Carry SCUBA Bottles	Lat Pull	.33	.11	-0.01	
	(constant)			7.21	.67
Pull Umbilical Line	Lean Body Wt.	.47	.22	0.00	
	(constant)			1.70	.18

* B is regression coefficient
** S.E.E. = standard error of estimate
N= 88 (Ladder), 125(Bottle), 118 (Umbilical)

DISCUSSION

This investigation found that Experimental Fitness Battery (EFB) scores can be used to predict job tasks reported by divers as representative of their work. Common factors in this relationship appear to be muscular strength and power. Therefore, it is not surprising that correlates of task performance included measures of strength (i.e., lat pull and leg press) and power (long jump).

The significance of lean body weight to job performance lies in the association between lean body weight and muscular strength. Previous studies have reported lean body weight to be significantly related to job task performance (7,8). Results of the present investigation showed lean body weight predicted a strenuous diving-related task (i.e., pulling a weighted umbilical line).

Although the EFB offers an improvement in job task prediction compared to current selection criteria, most of the variance in task performance was not accounted for by EFB scores. This finding would lead one to believe that other factors influenced job performance. Motivation and skill are important underlying factors that may have accounted for some of the variance in diving task performance. However, these factors were not measured during the study.

Age may influence physical performance. Previous studies on aging effects have concluded that work performance trends paralleled those followed by strength and endurance, generally peaking in the early thirties (9,10). The present investigation found no significant effect of age on diving task performance for the age range tested (18-37 yrs).

Gender also plays a major role in determining physical capability and work performance (8,11). Due to the small number of female diver candidates available for testing during the data collection phase, their results are not reported here. It is anticipated that additional women will be tested in the future so that gender-neutral standards may be developed.

Environmental factors, such as cold, have also been found to degrade diver performance (12-14). The influence of environmental stressors on task performance was beyond the scope of this investigation.

In summary, most diving tasks are complex and involve a mixture of physical and technical skills. Motivation is also an influential factor that adds to the complexity in predicting job performance. While the EFB offers an improvement in prediction of diving task performance compared to current screening procedures, caution is advised in

implementing the EFB for physical selection purposes. The majority of the variance in diving job performance is not accounted for by the EFB alone. The utility of these measures in a field setting is also unknown. Greater emphasis should be placed on aligning physical training methods to meet job performance requirements.

CONCLUSIONS

1. Current physical selection procedures may be improved using measures of body composition, power, muscular strength, and swim endurance.
2. Maximizing performance on fitness parameters relevant to the job will help to better match the diver-job interface.
3. Additional information is needed concerning female diver performance that will allow for the development of gender-neutral physical standards.

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